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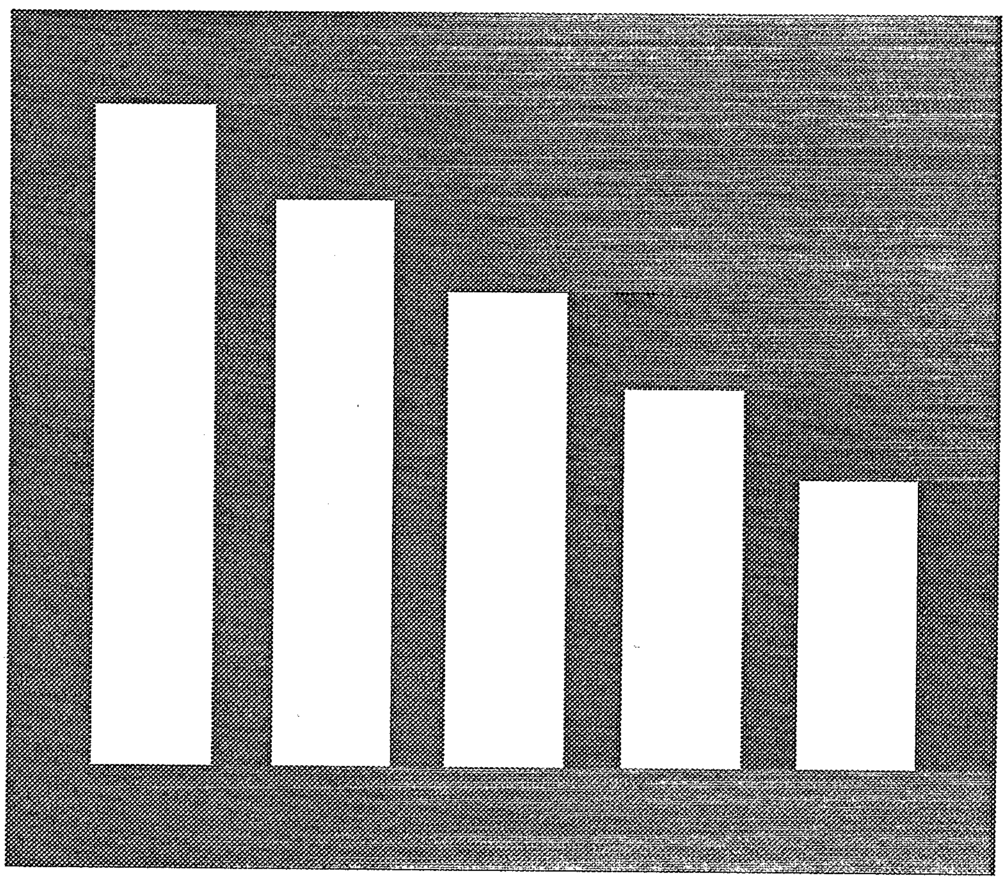
Why Accidents Occur: Insights From The Accidental Release Information Program

Chemical Accident Prevention Bulletin



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CHEMICAL ACCIDENT PREVENTION AND THE EMERGENCY PLANNING AND COMMUNITY RIGHT-TO-KNOW ACT OF 1986 (TITLE III)

In the wake of the chemical tragedy in Bhopal, India, the U.S. Congress enacted the Emergency Planning and Community Right-to-Know Act of 1986, also known as SARA Title III. Besides establishing state and local entities to plan for chemical emergencies, Title III requires facilities that handle hazardous chemicals to make information on the presence of those chemicals available to the public. Most of the initial steps in the Title III process were directed toward preparedness -- planning for possible chemical accidents. But the provision of information on chemical hazards and the dialogue with the public that such information creates can lead to a sharper recognition of hazards, actions to reduce those hazards, and, therefore, the prevention of chemical accidents.

EPA's report to Congress on chemical accident prevention, *Review of Emergency Systems* (June 1988), found that prevention of chemical accidents requires a holistic approach integrating technologies, procedures, and management practices. Sustaining a comprehensive approach depends on management's awareness of risks and commitment to safety. While the primary responsibility for accident prevention rests with industry, the circle of those involved with chemical safety is broad. It includes chemical manufacturers and distributors as well as the multitude of other businesses, such as furniture manufacturers and local dry cleaners, that routinely use hazardous chemicals. It covers every level of government and professional societies, trade associations, labor unions, the research community, environmentalists, and the general public.

Everyone has a role in encouraging industry to meet its responsibilities. Open communication, an understanding of the hazards, and a willingness to work together can bring us toward the ultimate prevention goal: no accidental releases.

WHY ACCIDENTS OCCUR: INSIGHTS FROM THE ACCIDENTAL RELEASE INFORMATION PROGRAM

INTRODUCTION

In this bulletin, EPA focuses on the causes of accidents, using information gathered through a pilot program -- the Accidental Release Information Program (ARIP). EPA established ARIP to promote safety initiatives by industry and to develop a national database on the causes of chemical accidents, but more important, to identify methods used to prevent recurrences. The purpose of this bulletin is to present insights drawn from the pilot program to local emergency planning committees (LEPCs) to help in dialogues with local facilities.

PREVENTION AND LEPCS

For you and for facilities in your community, the importance of understanding ways to prevent accidents is clear: preventing accidents is more effective in reducing risks and far less expensive than responding to accidents. The primary responsibility for preventing accidents must lie with industry. LEPCs and the public can, however, play an important role. With the information you have gained through the Title III planning process, you know which facilities in your community handle hazardous substances that may pose a threat to the community should an accident occur. You are, therefore, in a good position to decide which facilities should be the focus of prevention activities.

You can help your local facilities prevent releases of chemicals by engaging them in a dialogue about the hazards of their chemicals and processes, and about ways to reduce the chance of an accident. While some safety techniques are technical, the Section 305(b) final report to Congress, *Review of Emergency Systems*, indicated that plant management practices are critical to preventing releases. In your dialogue with industry, you can ask questions that address how the facility identifies and deals with hazards and the level of management's commitment to safety. The information in this bulletin can help you by identifying common problem areas --

chemicals that are frequently involved in accidents, common causes of accidents, and actions facilities have found useful to prevent further accidents.

ARIP: INVESTIGATING THE CAUSES OF CHEMICAL ACCIDENTS

A number of national databases on chemical accidents exist (see the Appendix for a summary description of these databases). Most were not designed specifically to address the causes of accidents; rather, they focus on information needed to determine an immediate response -- on what happened rather than on why it happened. Recognizing the shortcomings of existing information sources, EPA developed a questionnaire on the practices facilities use to prevent releases and on the techniques they use to assess hazards. Questionnaires are sent to facilities that report significant or frequent releases to the National Response Center; facilities are required to report any releases of certain chemicals if the releases exceed specified quantities. ARIP is now being fully implemented as a national program, but the Agency felt it was important to share lessons learned from the pilot with those who are talking with industry. (More specific information on ARIP and the pilot program findings can be found in the Appendix.) The findings that may be of use and interest to you include the following:

- The most frequently released chemicals in the ARIP database have been chlorine, methyl chloride, ammonia, sulfuric acid, and sodium hydroxide -- all large-volume, industrial chemicals.
- Most of the releases occurred at facilities that manufacture chemicals or other products.
- The quantity of chemicals released varies greatly.
- Although accidents commonly have more than one cause, the most commonly cited causes are equipment failure and operator error.
- About a quarter of the releases were from storage vessels, and a similar number from piping and process vessels. Valves and other equipment contributed to a smaller fraction of releases.
- Most releases occurred during routine processing of chemicals; loading, unloading, and maintenance played a lesser, but significant role.

These general findings suggest that LEPCs may want to focus first on facilities that use large volumes of hazardous chemicals. Manufacturers may need special attention because they use many hazardous chemicals and because they have many complicated processes where releases can occur. You should note, however, that some non-manufacturers also have large volumes of hazardous chemicals -- for example, public drinking water systems, non-residential swimming pools, and food storage facilities.

Brief summaries of three accidents reported in ARIP questionnaires, followed by a discussion of specific concerns raised by the ARIP findings, are presented below. Questions you may be able to use as you talk with facilities in your community are included for each area of concern.

ARIP ACCIDENT EXAMPLES

These examples are drawn from the more than 330 ARIP questionnaires received as part of the initial pilot. While these accidents are not the worst, nor are they typical (there is no such thing as a typical accident), they serve as useful illustrations of what can go wrong.

- A truck driver incorrectly identified the contents of his truck and began to unload hydrochloric acid into a facility tank containing nitric acid. The liquid mixture ate away the walls and bottom of the stainless steel tank. Although the spill was confined in a concrete containment, some of the mixed acid sprayed and splashed beyond the containment and a yellow cloud rose from the released liquid. Lime was applied to neutralize the acid mixture and a water fog was used to prevent further air contamination. To prevent a recurrence, the facility is installing new fittings on the nitric acid fill pipes that are incompatible with the hydrochloric acid fittings.

  Given the circumstances surrounding the incident, the facility could also have required, as part of a revised standard operating procedure, that an operator be present during all chemical deliveries to assure that the chemicals are properly identified and transferred and to keep unloading valves locked to prevent unauthorized use. This approach might have prevented such an error from occurring or halted the unloading at an earlier point.

- A steel manufacturer released 5,000 gallons of chromic acid plating solution from a storage tank. Although all valves to the tank and transfer pipe were in the proper position, the chromic acid leaked out over a three-day period. Upon further investigation, it was discovered that one of the valves was defective and another valve was badly corroded by the acid. Both valves have since been replaced with lined plug valves more suitable for contact with acid.

  In this case, the facility could also have run corrosion tests to determine the optimum material of construction for the valve, instituted a periodic corrosion inspection and valve maintenance program, and trained operators in the use of procedures or checklists to inspect for leaks and obviously corroded equipment.

- An aluminum sheet manufacturer with 3,000 employees released 1,700 pounds of chlorine gas for 13 minutes. An operator attempted to transfer liquid chlorine from a rail car to an evaporator building and the transfer hose failed. An investigation of the incident revealed that the hose was inappropriate for chlorine transfer operations. Consequently, all chlorine handling hoses are now specifically identified "For Chlorine Use Only." Also, the facility has installed a remote actuated chlorine shut-off valve and has conducted a hazard evaluation on the entire chlorine handling system.

  Conducting a hazard evaluation is a very positive step. In these circumstances, the facility should also stress that operators must always make sure the proper equipment is being used. This message could be reinforced through revised standard operating procedures and through a training course. The facility should consider ensuring that excess flow shut-off valves are used on all rail car transfers and investigate the possibility of using sensors, alarms, and automatic shut-off equipment.

These examples begin to indicate the complexity of the accident process; in many accidents, the release is the result of a number of factors and determining the cause as opposed to contributing factors can be difficult. The examples also illustrate the kinds of steps facilities can take to prevent recurrences.

PREVENTION INSIGHTS BASED ON ARIP DATA

The following sections present several prevention-related insights you can use when you talk with facilities. Each insight is supported by several ARIP statistics, descriptions of a few ARIP releases, and a list of specific questions suggested for LEPCs to use in discussions with local facility managers.

Operator Training: A Key to Preventing Human Error

Operator error was a primary or contributing cause in 31 percent of ARIP releases. Operator training can be a key to preventing human error: almost half of the facilities surveyed said they have a training program and consider it a significant release prevention measure. At facilities where operator error was the primary cause of the release, over 59 percent of the facilities noted that they considered upgrading or have already upgraded their training program. ARIP data also highlight the important role of standard operating procedures in preventing operator error. The following examples illustrate the value of training and standard operating procedures in preventing releases due to human error.

- A chlorine-caustic manufacturer released 500 pounds of chlorine gas for 20 minutes. An operator had failed to follow procedures, and the chlorine valves in the system were improperly set prior to the start-up of a pump. A temperature sensor for liquid chlorine, which could have provided some advance warning of the release, was not properly connected to the control room. Following the release, the facility properly connected the temperature sensor, conducted weekly tests of all control room alarms, developed an additional written procedure to assure that the valves are in the proper position, and investigated the incident using the plant's formal incident investigation process.

- A pulp and paper manufacturer released 100 pounds of sulfur dioxide due to operator error. The operators were instructed not to move certain chemical-filled containers in wet weather, possibly because the containers that were used were open or were not waterproof. Nonetheless, the chemicals were moved during a rainstorm. As a result of the incident, the facility has re-emphasized through additional training and practical exercises the standard operating procedures that prohibit the transport of certain chemical-filled containers in wet weather so operators understand the rationale for the procedure.

  Making sure that operators understand why a condition is unsafe is important, but it is also important to train workers to recognize when those hazards exist. Management should investigate alternative containers or *enclosures to protect the chemicals from exposure to water. Without these options, management forces operators to judge what are "wet" conditions rather than solves the problem.*

- A facility with 100 employees released vinyl chloride to the air because the operator mistakenly directed the chemical to an incinerator that was being repaired. In response, the facility now trains and requires the operator to follow a process checklist.

  The facility could have further guarded against operator error by programming the valves to close automatically, or manually closing, locking, and labelling them with "Do Not Operate" tags when any equipment is inoperable.

All employers covered by the Occupational Safety and Health Administration (OSHA) Hazard Communication Standard (HCS) are required to train their employees to work safely with various classes of chemical hazards. Training includes methods and observations used to detect releases of hazardous chemicals, the physical and health hazards of the chemicals, and methods to protect themselves. Facility records that document OSHA training should be available. Keep in mind as you talk with the facility that the type of training program used will vary with the facility. Individual training may be more feasible or effective than group training programs for some situations. The format of the training program is less important than the content and rigor of the program. Training is only effective if the operators understand what they are being taught. Therefore, a training course must include methods of testing operators to ensure they understand both the procedures and the reasons for the procedures. When operators understand the hazards of unsafe conditions, they will be more likely to work to avoid those conditions.

A last caution is that training alone cannot ensure error-free operations. In the practical world of industrial operations, there are limits on what even a well-trained operator can be expected to do. Part of management's responsibility is to structure tasks so operators can perform them safely during normal operating conditions and under stress. Managers need to be aware of the accident prevention role of "human factors technology" such as the design, layout, and locations of operating switches, alarms, and controls. For example, the switch for the hazard flashers in your car has become easier to use over the years because auto manufacturers recognized that it is important to find and operate the switch quickly in an emergency.

TRAINING QUESTIONS

The following questions may be used to start a dialogue with facilities in your community about facility training programs:

- Describe the training provided to workers. Which workers receive it? Are refresher courses offered? How often and for whom?
- Who gives the training? What are their qualifications?
- How are workers tested to see if they understand what they have been taught?
- Are workers retrained when processes or operating procedures are changed?

Equipment Failure: How to Limit It and How to Cope With It

Equipment failure was a primary cause of approximately 56 percent of the ARIP surveyed releases. This large percentage is not surprising because many factors contribute to equipment failure: lack of equipment inspections, lack of preventive maintenance, improper operation of equipment, poor equipment design, defective equipment, and age. The following incidents resulting from equipment failure were reported through the ARIP questionnaire.

- Seventeen hundred pounds of benzene overflowed a storage vessel during a loading operation. An alarm system designed to alert operators to high levels within the vessel on the tank malfunctioned. The operator had noted and logged the tank level before loading; however, he failed to appreciate the significance of the tank level measurement. As a result of the incident, the facility repaired and tested the high-level alarm system and connected this system to the control room. The facility has also installed safety valves that automatically shut down the benzene unloading pump on a high-level indication. For further assurance against a recurrence, the tank was refitted with an overflow pipeline which leads directly to an on-site recovery system.
- A facility producing nitrogen-based fertilizers and chemicals released ammonia vapors when a pipeline failed. The failed pipeline was repaired and reinforced

supports were added to reduce the vibration suspected of causing the failure.

The facility should also consider a periodic inspection program to identify trouble spots before failures.

- A petroleum refinery with over 1,500 employees released almost 200 pounds of hydrogen sulfide into the air. The release was the result of a power failure and a resulting over-pressurization in an operating unit, possibly causing a relief valve or rupture disk to open. The facility installed a new alarm system to alert operators that a back-up power supply (batteries) has been activated when a power failure occurs. The alarm warns that operations personnel must secure the unit within 30 minutes to avoid atmospheric releases.

  All facilities should ensure that equipment is "fail safe" in the event of a power failure and recognize the impact and consequences on a process unit when power failures occur. In addition, facilities need to recognize and evaluate the consequences and impacts of controls used to prevent a hazard. In this example, relief valves or rupture disks may have been used to prevent the unit from rupturing if over-pressurization occurred. However, safeguarding the unit this way leads to emergency venting to the air. The facility then needs to evaluate if a scrubber or other methods of pressure reduction could eliminate releases of the substance to air.

Hazard Evaluation: Identifying Problems Before They Happen

No one likes to think about accidents, but one way to prevent them is to analyze what would happen if one piece of equipment fails, or a chain of equipment failures and human errors occurs. This process is called *hazard evaluation.* The American Institute of Chemical Engineers has published guidelines for hazard evaluation techniques; these guidelines explain 11 hazard evaluation techniques -- how they are conducted, when they are appropriate, how long they may take, and who needs to be involved.

The type of hazard evaluation technique used depends on the facility and its processes. A small facility with, for example, two vessels, a pump, and four employees can work through one of the simpler techniques fairly quickly. A larger facility may need several months to identify all the possible failures and their consequences. The important thing is that the analysis is thorough and that possible problem areas, such as inappropriate equipment, are addressed once the analysis is complete.

What should be of concern to you is how the facilities identify equipment that is likely to fail or has failed. Many accidents occur because one piece of equipment such as a pressure gauge fails, no one notices, and pressure builds, leading to a release. Installing the best equipment will not solve the release problem by itself; the facility must have preventive maintenance procedures, make use of reliability information for equipment, and consider what they will do if the equipment does fail. All of these factors must be addressed in a holistic approach to preventing accidental releases.

HAZARD EVALUATIONS AND EQUIPMENT FAILURE QUESTIONS

- Has the facility conducted a hazard evaluation? What kind and when was it performed? What recommendations resulted from the evaluation? Were they implemented?
- What procedures are in place to address equipment failure? Are workers aware of and trained in design and operating specifications?
- What does the facility consider to be critical equipment?
- How do they know when critical equipment has failed?
- What happens if critical equipment fails?
- Does the facility investigate all accidental releases? What actions have been taken as a result of accident investigations? Will the facility share the results with other facilities, the LEPC, and other organizations?

Inspection and Maintenance: A Key to Preventing Equipment Problems

Equipment inspections can spot potential releases before they happen (e.g., thin pipe wall, loose valve). Regular maintenance of process equipment helps to prevent equipment failure and accidental releases. Over 25 percent of the facilities in the ARIP database indicated that prior to the release, they maintained an inspections program on the equipment or systems that caused the release. Only four percent indicated that they performed preventive maintenance on the failed equipment or system; preventive maintenance checks or replaces equipment before it fails. The following examples illustrate uses of inspection and maintenance on process equipment to help prevent releases.

- A petroleum refinery released 2,000 pounds of hydrofluoric acid gas because of a pipe leak. As a result, the facility started an annual pipe inspection program using radiography (X-rays) to identify actual or potential piping failures without having to disassemble the piping. The program uses computer records to prompt inspections and gives special attention to critical piping.

- A manufacturer of agricultural chemicals released 13 pounds of chlorine gas due to a leak in piping. Operations and maintenance personnel at the facility regularly conduct piping inspections to identify lines and fittings that show significant metal loss or other characteristics that might lead to a failure. However, this procedure failed to prevent the leak. As a result of the release, the piping inspections program has been upgraded to include more frequent inspections and improved documentation.

- Hydrochloric acid leaking from a small crack in a pipe elbow corroded the leg supports of a nearby drain pipeline that also contained hydrochloric acid. The eventual collapse of the supports caused a one-inch opening in the connections in the drain pipeline. Consequently, almost 200,000 pounds of hydrochloric acid were spilled. Henceforth, the acid pipelines will be visually inspected once a week. Also, the facility installed a new process line constructed of more corrosion resistant material.

Maintenance and inspection programs are key elements of accident prevention. Facilities should have programs for inspecting all their equipment. For critical elements such as pressure gauges, preventive maintenance is needed. Where manufacturer's information or facility experience indicates that equipment has a limited useful life, the equipment should be replaced before it fails. Gauges and monitors should be calibrated periodically. The frequency of needed calibration varies with the instrument. Some monitors hold their calibration for months; other must be calibrated weekly. Facility experience or information from the manufacturer probably indicates how frequently instruments need recalibration to ensure accuracy. Inspection and maintenance schedules should be written and tracked, and all maintenance should be logged so a manager can check the written record to know what has been done and what needs to be done. One aspect of maintenance that LEPCs should not overlook is emergency response equipment. Because this equipment is used infrequently, the facility should test it as well as inspect it to ensure that the equipment will function whenever it may be needed.

MAINTENANCE QUESTIONS

- Does the facility have a written maintenance program, with schedules?
- Do they keep a log of when each piece of equipment is checked and replaced?
- Do they train maintenance employees on proper procedures?
- Do they have a schedule for replacing critical elements even if they are not noticeably worn?
- Have they had problems with particular equipment? If so, did they change their inspection or maintenance schedules?

APPENDIX

SUMMARY OF THE ARIP DATABASE AND FINDINGS FROM THE PILOT

Databases on Hazardous Chemical Accidents and Prevention

ARIP is unique among databases concerning chemical accidents because of its focus on the causes of accidents. Several other accident databases often referred to in discussions of accident prevention are:

- The *National Response Center* (NRC) database, consisting of release reports received under the Superfund (CERCLA) requirement that parties report to the NRC hazardous substance releases exceeding specified reportable quantities. NRC reports are used as a mechanism for notifying federal On-Scene Coordinators and determining the need for federal response.
- The *Acute Hazardous Events Database* (AHE/DB) on the causes and consequences of releases is compiled by EPA from a wide variety of sources, including NRC reports and press stories. AHE/DB provides EPA with qualitative, largely anecdotal information about chemical accidents and does not address preventive actions.
- The *Emergency Response Notification System* (ERNS), compiled by EPA from reports to the NRC, the Coast Guard, and EPA Regional Offices, is a national database used to collect information on releases of oil and hazardous substances as well as subsequent responses to such releases. ERNS is used by EPA for enforcement tracking and program management purposes.
- The *Hazardous Materials Information System* (HMIS), based on written reports transport carriers are required to file, is the central system for hazardous materials transportation spill data.

How Releases Are Targeted for Inclusion in the ARIP Database

The data collected in ARIP are derived from questionnaires completed by selected facilities that have reported releases to the National Response Center (NRC), as required by law.

Facilities selected to receive an ARIP questionnaire have experienced a "triggered" release exhibiting one or more of the following characteristics:

- Release quantities in excess of a multiple of the CERCLA reportable quantity for the chemical involved;
- Releases resulting in deaths or injuries;
- Releases that are part of a trend of frequent releases from the same facility; or
- Releases involving extremely hazardous substances designated under Title III.

The Uses of ARIP Data

The ARIP database and program have been designed to serve multiple purposes, including:

- Uncovering national trends in the chemicals and processes involved in releases, the causes of releases, and release prevention practices used by facilities;
- Identifying "accidents waiting to happen," i.e., facilities showing a persistent pattern of small releases that may foreshadow more severe future releases, and calling attention of facility management to the problem;
- Heightening corporate awareness and involvement in preventing accidental releases through the consciousness-raising device of the questionnaire; and
- Providing LEPCs and SERCs with important information useful both in preparing Title III-mandated emergency response plans and in working with facilities to reduce hazards through prevention.

ARIP's Limitations

Although ARIP is the best available database on the causes of, and means of preventing, chemical accidents, it, too, has its limitations. These limitations must be kept in mind in deriving conclusions and recommendations from ARIP. The most important limitations of the ARIP data include:

- ARIP is a database in its formative stages -- current "results" are preliminary in nature because they are based on information from only approximately 330 releases. Also, the questionnaire has been recently expanded as a result of the Section 305(b) study. Data from many more releases will be analyzed and included in the database as it grows.

- The screening criteria or triggers chosen to narrow the universe of releases covered by questionnaires intentionally skew the database to larger, more severe, and more frequent releases. The designers of ARIP considered this bias sensible from an environmental and public health standpoint.

- Because the NRC database defines the universe of releases that are subject to the ARIP screening triggers, releases involving numerous toxic and hazardous chemicals that are not subject to CERCLA and Title III reporting requirements are not included in the ARIP database.

ARIP Pilot Results

There are several tentative conclusions that can be reached based on the information in ARIP questionnaires received to date:

Most Frequently Released Chemicals (Exhibit 1)

The most frequently released chemicals reported in the ARIP database are chlorine, methyl chloride, ammonia, sulfuric acid, sodium hydroxide, and hydrochloric acid. These are all common, large-volume industrial chemicals. They are also among the most frequent releases of hazardous substances in the NRC and Acute Hazardous Events (AHE/DB) databases. In fact, the six most frequently released ARIP chemicals are the same six chemicals most frequently reported in the AHE/DB.

Industries Most Frequently Involved in Accidental Releases (Exhibit 2)

In the ARIP questionnaire, facilities identified their primary area of business based upon Standard Industrial Classification (SIC) code designations. More than 89 percent of the facilities are from the manufacturing sector (SIC codes 20-39). Moreover, more than 69 percent of all facilities are specifically involved in chemical manufacturing and petroleum refining

(SIC codes 2800-2900). Consequently, ARIP results reflect the releases of producers and industrial users rather than other, more numerous facilities in the non-manufacturing sector.

Quantities of Chemicals Released (Exhibit 3)

Both large and small chemical releases are reported to the NRC. The ARIP releases also vary greatly because they are selected from a sample of the NRC releases. More than half (177 of 332) of the reports cover releases of 1,000 pounds or more, and over four percent of these releases were 100,000 pounds or more. On the other end of the scale, about nine percent of the reports showed less than 10 pounds released; those reports were for accidents selected because a death or injury was reported or because the facility had a number of repeat releases. The size of the release is not always a valid measurement of the seriousness of the release. The questionnaires verified that both large and small releases can cause extensive damage, public evacuations, injuries, and death.

Most Common Causes of Releases (Exhibit 4)

Primary causes and the whole spectrum of contributing causes of releases are difficult to define and distinguish (e.g., an operator's failure to activate the correct valve may cast doubt on both the operator and the facility's training program). Recognizing this difficulty, ARIP results show equipment failure (56 percent) and operator error (24 percent) as the most frequently reported primary causes of releases. This seems reasonable: causal information in the AHE/DB confirms the relative importance of these two primary causes. From a release prevention standpoint, operator error is usually addressed with training programs and revised standard operating procedures. Equipment failure is usually addressed through regular inspections, maintenance, equipment, design, and choice of construction material.

Nearly 10 percent of releases were attributed to "upset conditions" (e.g., overpressurization) or "bypass conditions" (e.g., detouring chemicals around the main chemical processing pathway). These conditions result from a variety of causes, including operator error, equipment failure, and poor system design. Consequently, the measures used to prevent releases from upset and bypass conditions depend greatly on the individual details of the incident. A significant number (38 percent) of ARIP releases were attributed to more than one cause. Among these releases, the most commonly cited secondary causes were equipment failure, operator error, and other unspecified causes.

In-Plant Location of Releases (Exhibit 5)

ARIP information also permits analysis of the most common locations of releases within facilities. The data indicate that ARIP releases occurred with roughly similar frequency in process vessels, storage vessels, and piping (approximately 25 percent each). Releases from valves are slightly less frequent (11 percent). Data on release location in the AHE/DB indicate a similar distribution of releases from process vessels, storage vessels, and piping/valves. Consequently, an effective release prevention program must examine all the parts and equipment involved in the facility's chemical processing.

Process Status When Releases Occur (Exhibit 6)

ARIP explores the relationship between the incidence of accidental releases and the different phases of a chemical process. Typically, chemical facilities use either a batch process or a continuous process. In a batch process, the raw chemicals are basically added to one or several containers (e.g., vats) or processing equipment (e.g., evaporator, distiller) and then subjected to specific temperatures, pressures, and agitations for a discrete time to produce a batch of the desired product. Paint manufacturers use batch processes to produce different colored paints. In a continuous process, the reactants continuously flow through a series of processing equipment to produce a continuous flow of product. Petroleum refineries use continuous processes. Separate from these process operations are the procedures to load the raw chemical reactants from a supplier (e.g., truck, railcar) to the facility's storage and to unload the chemical products to the shipper. Also, both batch and continuous operations require process start-up and shutdown procedures. Releases can occur during any of these procedures as well as during the operations mode (e.g., application of heat, mixing) of the batch or continuous processes. ARIP also examines the incidence of releases when maintenance is being performed on process equipment.

The largest number of ARIP releases (153 cases or 45%) occur during continuous processes. The wide variety of continuous processes used by the chemical industry and consequently, the resulting diversity and integration of process equipment may be responsible for this high incidence of accidental releases. A significantly lower number of releases (34 or 10%) occur during batch processes. More than 16 percent of releases (56 cases) occur during loading or unloading procedures. A similar percentage (14% or 46 cases) of releases occur during either process start-up or shut-down. Chemicals released while maintenance is performed account for less than five percent.

PILOT ARIP RESULTS

Exhibit 1
MOST FREQUENTLY RELEASED CHEMICALS

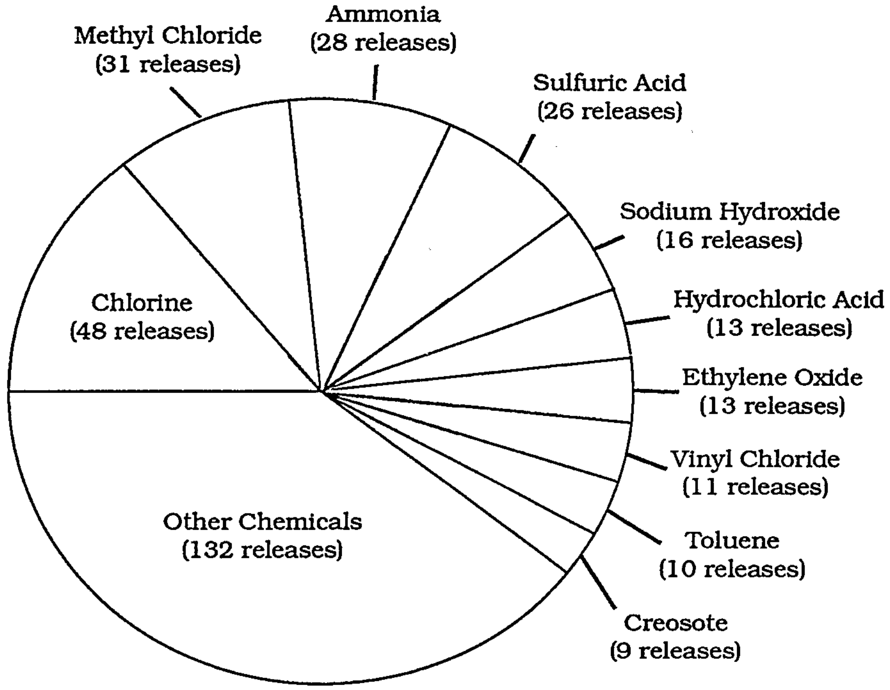
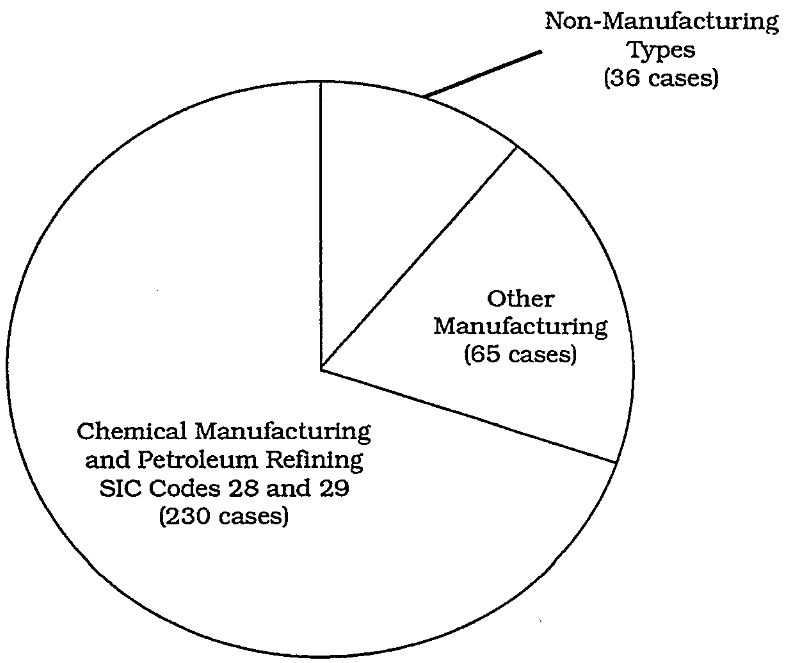
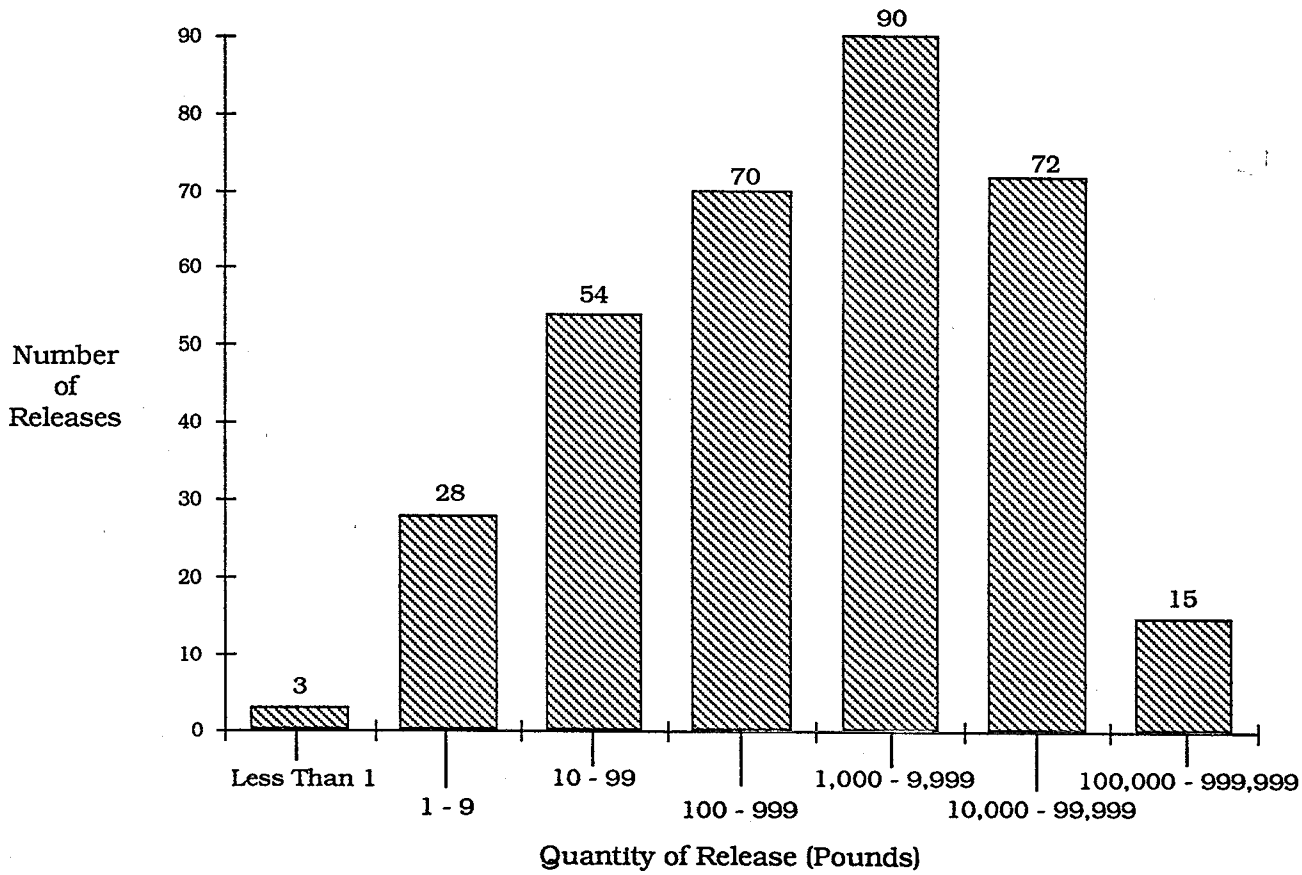


Exhibit 2
INDUSTRIES MOST FREQUENTLY INVOLVED IN ACCIDENTAL RELEASES



PILOT ARIP RESULTS

Exhibit 3
QUANTITIES OF CHEMICALS RELEASED



Note: Quantities were not given for five releases.

PILOT ARIP RESULTS

Exhibit 4
MOST COMMON CAUSES OF RELEASES

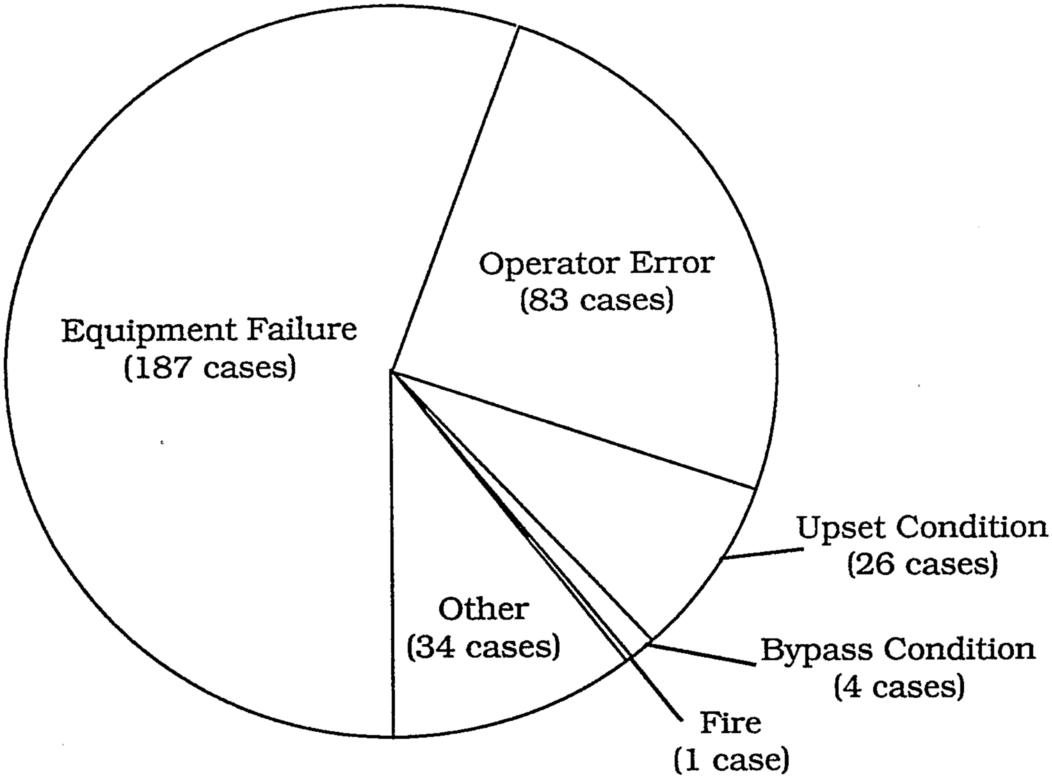
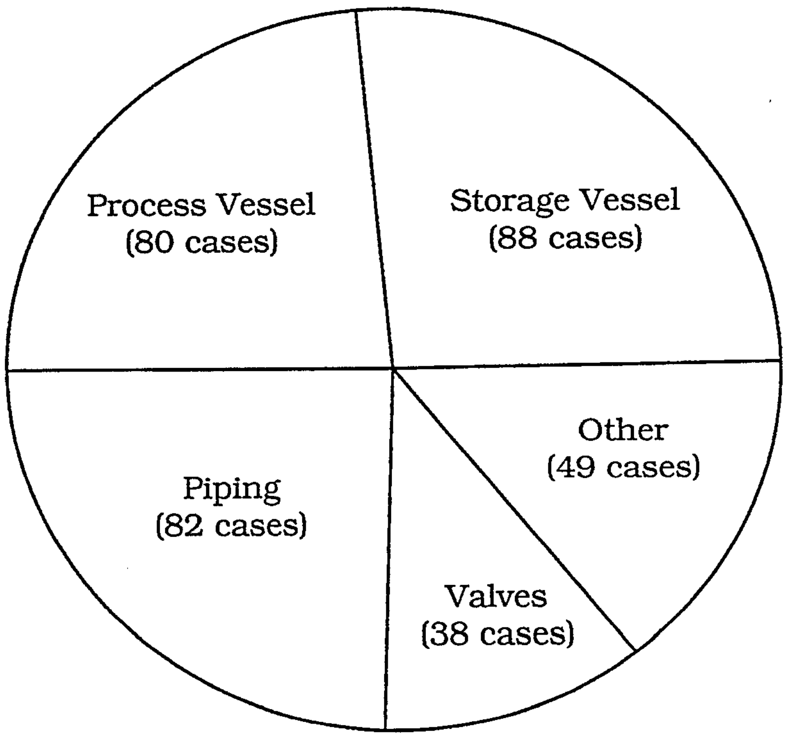
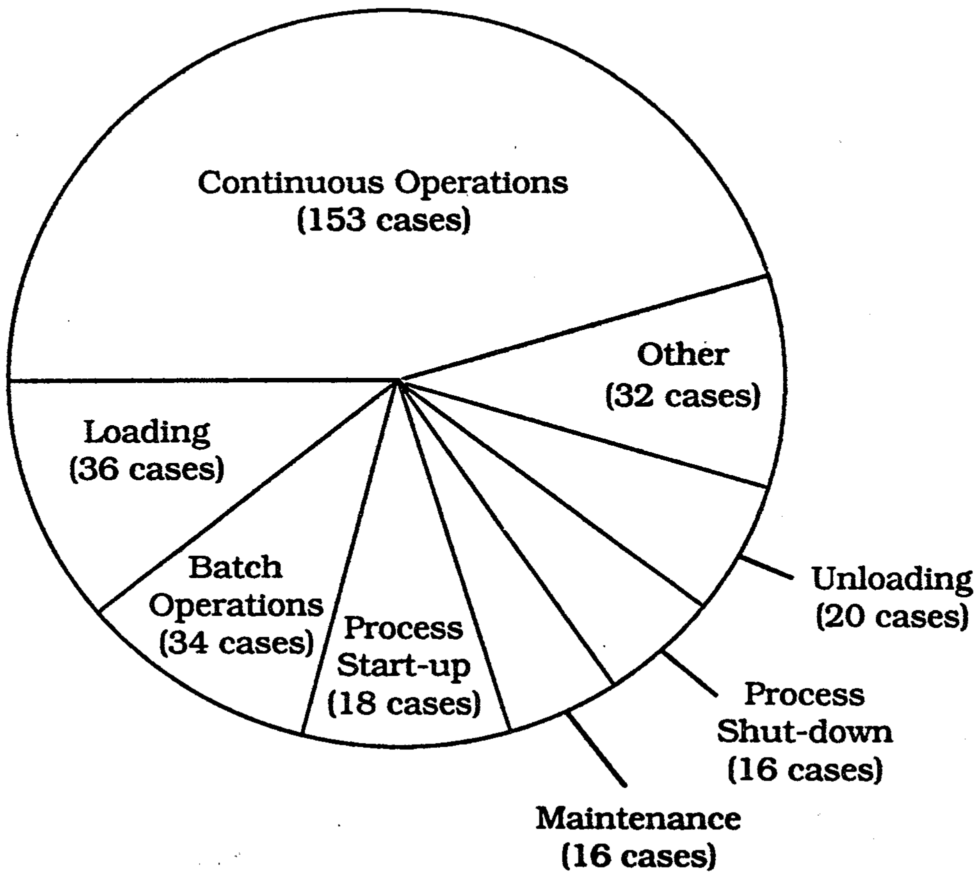


Exhibit 5
IN-PLANT LOCATION OF RELEASES



PILOT ARIP RESULTS

Exhibit 6
PROCESS STATUS WHEN RELEASES OCCUR



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